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INFORMATION ON RESPONSE REQUIREMENTS COMPARED WITH INFORMATION ON FOOD DENSITY AS A REINFORCER OF OBSERVING IN PIGEONS

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On a variable-interval schedule, pecking the key to the pigeon's right (observing response) produced red or green displays relating to the delivery of grain and its dependence on pecking the key to the left (food key). During various blocks of sessions, mixed (no stimulus change) schedules including the following pairs of components were temporarily converted by the observing response to their corresponding multiple (correlated stimuli) schedules: variable-interval 60-s, extinction; variable-interval 60-s, variable-time (response-independent) 60-s; extinction, variable-time 60-s. Differences in food delivery maintained substantial rates of responding on the observing key, without regard to pecking requirements on the food key. Although stimuli correlated with differences in the response requirement on the food key maintained higher observing rates than those maintained by uncorrelated stimuli, they were much lower than those based on food. The value of predictive stimuli as reinforcers is determined by the value of the events predicted. In particular, the cost of pecking appears to be low, and this may place limitations on the applicability of energy-based and economic models of behavior.

Key words: observing, response cost, response-independent reinforcement, information, conditioned reinforcement, expectancy, optimization, key peck, pigeons

When a response produces stimuli predictive of behaviorally effective events like food or shock but has no material influence on the schedule on which those events are delivered, it is known as an "observing response" (Wyckoff, 1952). Because the function of this type of behavior is merely to bring the subject into contact with the relevant stimuli, rather than to produce the ultimate reinforcer, it is considered analogous to natural responses like tasting, touching, or looking at the stimulus object. Often the stimuli made available by such a response are discriminative for other behavior, and it seems likely that natural forms of observing play a critical role in the reduction of the initial generalization between the positive and negative stimuli during the acquisition of stimulus control (Dinsmoor, 1985). Most of the research, however, has focused on the problem of accounting for the acquisition and maintenance of the observing response itself, a response that does not affect the schedule on which the food or shock is delivered (for reviews, see Dinsmoor, 1983; Fantino, 1977).

Reinforcement theorists attribute observing to conditioned reinforcement but diverge in their interpretations of how this comes about (e.g., Daly, 1986; Dinsmoor, 1983, 1986; Fantino, 1983; Perkins, 1983). Cognitive theorists commonly think of the living organism as a system that regularly and ubiquitously gathers information about sequences of events in the surrounding environment (e.g., Boneau, 1974; D'Amato, Etkin, & Fazzaro, 1968; Dember, 1974; Dickinson, 1980; Gibson, 1969; Schrier, Thompson, & Spector, 1980). From this assumption, it follows that information about forthcoming events must, in the language of the present writers, be reinforcing. Although not all supporters of the information hypothesis agree, many sympathize with the view expressed by Lieberman:

> These divergent explanations can be considered as part of a larger theoretical conflict between cognitive and reinforcement interpretations of learning. In this sense, the secondary reinforcement interpretation suggests that organisms engage in observing behavior because of a specific history of reinforcement for such behavior, while the information hypothesis implies that observing behavior is merely part of a larger cognitive process directed toward active exploration and interpretation of the environment. Observing behavior in this view is not simply an automatic response directed toward reinforcing stimuli, but an active search for any stimuli that are informative about future events, whether good or bad. (Lieberman, 1972, pp. 341-342)

Empirical findings, however, have not been supportive of the information hypothesis. Much of the early argument was concerned with information about the schedule of food delivery and specifically with the issue of whether the negative discriminative stimulus (S−) is reinforcing. Most investigators who have examined that issue have concluded that it is not (for review and discussion, see Dinsmoor, 1983). The strongest evidence for the contention that S− is reinforcing came from the work of Lieberman, but Mueller and Dinsmoor (1984) were able to reproduce Lieberman's results under circumstances that indicated that the original interpretation was not correct, and Mueller and Dinsmoor (1986) have offered an alternative interpretation of those results. In recent years, attention has turned to other forms of information. For example, Bowe and Dinsmoor (1981, 1983) tested the effects of stimuli indicating which key must be pecked to produce grain and found that this form of information did not maintain observing. In the present research, we examine the effects of stimuli that indicate whether pecking is necessary to procure food.

With human subjects, much of the controversy has revolved about the role played by response cost or effort (Case, Fantino, & Wixted, 1985; Perone & Baron, 1980), and the argument has spilled over to the role played by the same factor in experiments using pigeons (Dinsmoor, 1983; Perone & Baron, 1983). In private communications, too, it is frequently assumed that by producing a stimulus in the presence of which no pecking of the food-delivering key is "required" (negative discriminative stimulus), the pigeon can economize on the energy it expends in procuring the food (see also Steiner, 1970). In turn, this reduction in effort is thought to provide the biological gain necessary to account for the pecking of the observing key. Unfortunately for the response cost or effort hypothesis, the rate of pecking the food key goes up in the presence of the positive stimulus as well as down in the presence of the negative stimulus, and quite often the net result is more pecking, on the average, when the bird has produced the discriminative stimuli (multiple schedule) than when it remains on the mixed schedule. Data relevant to this issue have been published by Bower, McLean, and Meacham (1966, p. 189), Dinsmoor, Browne, and Lawrence (1972, p. 83), and Hirota (1974, p. 266). To deal with the issue directly, however, it may still be worthwhile to determine how much influence the presence or absence of a pecking requirement for production of grain has on the pigeon's observing behavior.

METHOD

Subjects

Eight female White Carneau pigeons, approximately 1 year of age, were maintained at 80% of their free-feeding weights with supplementary feedings following the experimental sessions. Water and grit were continuously available in each bird's home cage. Before they served in the present study, the birds had participated in a discrete-trials discrimination experiment in which red and green signal lamps served as the stimuli and pecking an amber key as the response.

Apparatus

During the experimental session, the birds were placed in a Coulbourn Instruments pigeon chamber measuring 25 cm across the front panel, 27.5 cm from front to back, and 30 cm in height. The chamber was housed in a sound-attenuating enclosure in a room separate from the one containing the electromechanical equipment that controlled and recorded experimental events. On the front panel there were two response keys, a houselight, and an opening giving access to a food hopper. The response keys were small rectangles of translucent plastic suspended behind circular openings 2.5 cm in diameter. They were aligned horizontally 15 cm apart, center to center, and 24 cm from the floor of the chamber. Behind each key was a metal housing containing three Type 1829 (28 V dc) bulbs, each covered with a plastic cap, so that the key could be illuminated with red, green, or amber light. The houselight was another Type 1829 bulb, partially shaded by a metal housing, centered laterally 2 cm below the ceiling. The rectangular opening to the food hopper measured 5.5 cm high and 5 cm across; it was located below and midway between the two response keys, with its lower edge 2.5 cm above the floor.

Procedure

Throughout the first four sessions, the left key was always amber and the right key always dark. On the first session, each bird was trained by successive approximation to peck the left (food) key. To reinforce this response, the hopper was raised for 2.5 s; during this time, the hopper was lighted from above and all other illumination was extinguished. Once pecking began, the next 30 instances were reinforced on a continuous schedule, and the session was then terminated. On the second session, the grain was made available on a variable-interval (VI) 15-s schedule, on the third session on a VI 30-s schedule, and on the fourth session on a VI 60-s schedule. The intervals for all VI and variable-time (VT) schedules were determined by the formula published by Fleshler and Hoffman (1962). The second and third sessions terminated after 60 presentations of grain; for the remainder of the experiment, all sessions lasted 60 min.

Except where noted, the following procedure was used for all subsequent sessions. Both keys were initially amber. On a VI 30-s schedule, pecking the right (observing) key produced 30-s periods during which that key was darkened and the left (food) key was illuminated with red or green light. Except under the uncorrelated procedure, to be described below, the color of the food key during one of these displays was determined by the schedule on which the grain was currently being delivered. The schedules themselves alternated at intervals of unpredictable duration averaging 20 s. If the schedule changed during a display, the color of the key changed with it.

The birds were tested under four experimental conditions, which differed in terms of the component schedules and their relation to the green or red illumination of the food key. Individual birds were exposed to these conditions in different orders and for varying numbers of sessions, as specified in Table 1. There and throughout this paper, the schedule listed first is the one that accompanied green illumination of the food key and the schedule listed second is the one that accompanied red. A bird was exposed to a given condition until its behavior was judged to be stable.

VI/EXT. Under this condition, the schedule of reinforcement alternated between VI 60-s and extinction (EXT). During the VI component, pecks on the food key were followed by 2.5 s of access to the grain on the average of once every 60 s. During the extinction component, grain was never made available. When the bird produced a stimulus display by pecking the observing key, the VI schedule was accompanied by green illumination of the food key and periods of extinction by red.

VI/VT. The schedule of reinforcement alternated between a component in which a response was required before grain was delivered (VI, as described above) and one in which no response was required but otherwise the distribution of intervals between reinforcements remained the same (VT). During the VI component, pecks on the food key were followed by access to grain on the average of once every 60 s; during the VT component, presentations of grain occurred, on the average, once every 60 s. In this case, however, a peck on either key within 2 s before a scheduled presentation postponed receipt of the grain until 2 s had elapsed without a peck. When the differential stimuli were displayed, the VI component was accompanied by green illumination of the key, as before, and the VT component was accompanied by red.

Uncorrelated. The component schedules for the presentation of grain were the same as in the previous condition (VI/VT). However, the colors produced by pecking the observing key alternated between green and red at an average interval of 20 s on a schedule independent of that employed to switch between the component schedules for grain. Therefore, there was no correlation between the color on the key and the schedule for delivery of food.

EXT/VT. Finally, extinction and VT were paired as the alternative components in the schedule for presentation of grain. When the differential stimuli were on display, the periods of extinction were accompanied by green and the periods of response-independent grain delivery by red.

Transitions. Before beginning its exposure to the VI/EXT, VI/VT, or EXT/VT conditions, in most instances each bird received seven sessions of preparatory training designed to facilitate a rapid approach to asymptotic performance. For the first three of these sessions, the bird was exposed to a multiple schedule like that which it would face when pecking the observing key had produced the subsequent stimulus display. For example, training for transitions to VI/VT involved three sessions in which the food key was always green during the VI component and always red during the VT component. The observing key was dark and had no function. The next three sessions provided exposure to the mixed schedule. The

Table 1

For each bird: number of sessions under each procedure, rate of pecking observing key while lighted, rate of pecking food key while amber, green, or red, and frequency of grain delivery while amber, green, or red. In procedural abbreviations, the first term specifies the schedule in green, the second that in red. Amber accompanied the mixed schedule.

Subject	No. of sessions	Pecks/minute observing key	Pecks/minute food key			Grain deliveries per minute		
			A	G	R	A	G	R
Bird 20								
VI/EXT	39	5.99	91.51	114.15	1.92	0.54	1.00	0
VI/VT	93	2.84	30.66	59.09	1.53	1.03	1.05	1.17
Uncorrelated	21	0.59	25.96	39.22	11.04	1.03	0.96	1.13
VI/VT	32	0.77	33.28	59.05	1.10	1.02	1.02	0.97
EXT/VT	38	10.63	0.13	1.78	0.66	0.53	0	1.04
Bird 21								
VI/VT	15	0.15	28.30	55.65	2.59	1.03	1.12	1.67
VI/EXT	86	3.72	44.70	46.79	0.20	0.55	1.05	0
VI/VT	52	1.40	26.78	50.18	0.24	1.03	1.06	1.06
Uncorrelated	26	0.32	23.69	31.61	20.28	1.03	1.06	1.19
EXT/VT	42	0.80	2.16	0.22	0.19	0.54	0	0.90
Bird 22								
VI/VT	79	1.62	32.56	71.24	0.19	0.95	1.04	1.18
Uncorrelated	19	0.92	28.39	36.84	12.37	0.97	0.93	0.86
VI/EXT	93	4.49	53.17	50.66	0.11	0.53	1.10	0
EXT/VT	43	6.39	0.07	0.02	0.03	0.50	0	1.09
Bird 25								
VI/EXT	39	9.53	38.07	60.67	0.18	0.49	1.08	0
VI/VT	93	2.46	21.16	26.28	0.24	1.04	1.05	1.07
Uncorrelated	21	0.46	17.23	29.85	0.15	1.09	0.71	0.95
VI/VT	32	1.03	16.33	25.40	0.10	0.99	1.23	1.13
EXT/VT	38	4.15	0	0	0.24	0.55	0	1.08
Bird 26								
VI/EXT	69	4.23	46.13	66.57	0.34	0.53	1.09	0
VI/VT	38	0.26	20.08	25.81	0.28	1.02	1.07	1.09
EXT/VT	43	2.75	0.03	0.04	0	0.56	0	1.01
Bird 27								
VI/VT	12	0.87	24.58	53.77	0.57	0.99	1.22	1.21
VI/EXT	62	12.73	36.68	50.24	0.13	0.56	1.03	0
VI/VT	49	0.80	23.65	42.37	0.13	1.00	1.20	1.25
Uncorrelated	16	0.07	23.61	32.19	3.83	1.01	0.88	1.55
EXT/VT	65	16.77	1.32	0.08	0	0.55	0	1.05
Bird 28								
VI/VT	5	1.33	25.89	22.87	2.57	1.00	0.69	1.40
VI/EXT	84	13.56	98.23	131.60	20.90	0.54	1.17	0
VI/VT	50	0.72	29.66	88.50	0.71	1.00	1.04	1.15
Uncorrelated	24	0.03	29.25	42.23	60.61	1.03	1.03	0.75
EXT/VT	68	6.14	0.02	0.03	0.26	0.54	0	1.01
Bird 29								
VI/EXT	39	5.35	60.51	87.64	0.41	0.51	1.10	0
VI/VT	91	5.52	41.99	73.23	0.29	1.00	1.02	1.24
Uncorrelated	22	2.98	40.40	54.81	15.79	1.10	0.96	0.98
VI/VT	33	3.84	49.28	55.73	0.73	1.02	0.96	1.20
EXT/VT	38	7.12	0.13	1.03	0.34	0.53	0	1.10

schedules of reinforcement on the food key alternated as before, but the key remained amber. Again the observing key remained dark and pecks had no programmed consequence. During the final session of preparatory training, the food key was dark and the observing key was amber. Pecking the food key had no programmed consequence, but pecking the observing key produced deliveries of grain on a VI 60-s schedule.

No preparatory training was employed prior to the uncorrelated condition or for Birds 20, 25, and 29 in the transition from the uncorrelated condition to their second exposure to VI/VT.

RESULTS

The data from each bird under each experimental condition, in the order in which they were collected, are presented in Table 1. Observing-key rates, in pecks per minute, were averaged for the last five sessions under each condition (see Figure 1). Food-key rates in the presence of each of the colors (A = amber, G = green, and R = red) were treated in corresponding fashion. Finally, the number of grain deliveries per minute was also calculated with each color for each bird and averaged for the entire block of sessions under a given condition.

Mean food-key rates were usually appropriate to the schedule of reinforcement prevailing for a given key color at the time the data were collected. The highest rates were usually obtained in the presence of green illumination of the key when that color was accompanied by a response-dependent (VI) schedule (VI/EXT, VI/VT). The lowest rates were usually obtained in the presence of red when that color was accompanied by extinction or a response-independent schedule (VI/EXT, VI/VT, EXT/VT) and in the presence of green when that stimulus was accompanied by extinction (EXT/VT). Food-key rates in amber, which served throughout as the mixed stimulus, were typically intermediate between those in green and those in red. Under the uncorrelated condition, food-key rates in green or red were not usually as high as when green was consistently accompanied by a VI schedule or as low as when red was consistently accompanied by VT or EXT, but did appear to reflect previous schedules of reinforcement in each color. The rate in the presence of red, for example, was often much lower than the rate in the presence of green, although in all subjects but Bird 25 it was higher under the uncorrelated condition than under any other procedure.

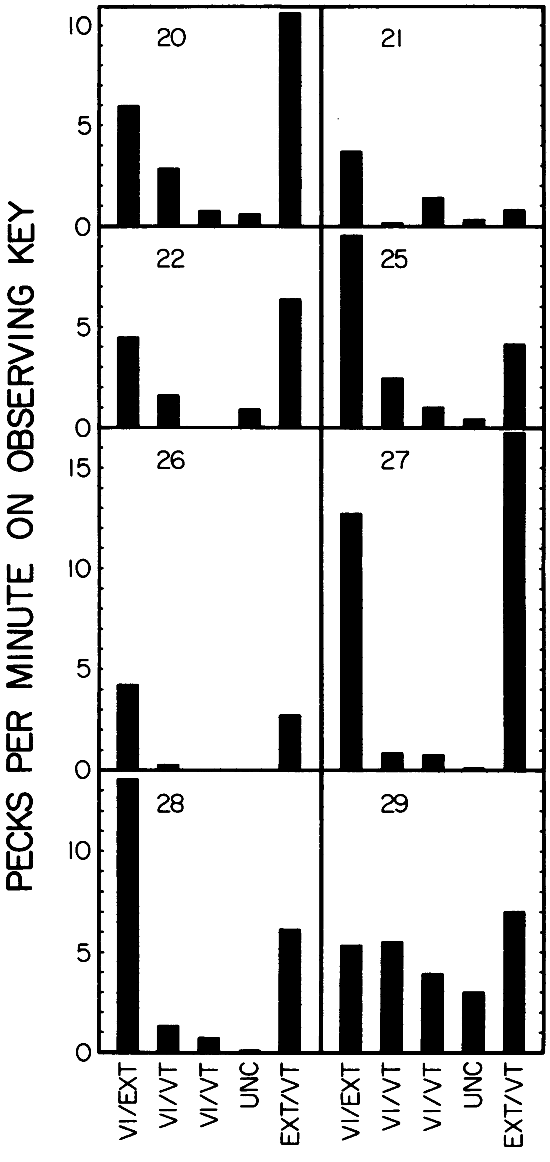

Fig. 1. Mean rate of pecking the observing key, when lighted (mixed schedule), during the last five sessions under each procedure. The first abbreviation specifies the schedule accompanied by green illumination of the food key during the discriminative displays and the second abbreviation that accompanied by red. No data were collected for Bird 26 under the uncorrelated procedure, and the VI/VT data were not replicated for that bird or for Bird 22.

The data of primary interest, of course, are the rates at which the pigeons pecked the observing key, when lighted (i.e., during the mixed schedule), under each of the experimental conditions. For ease of comparison, these data have been arranged in a systematic order and displayed in the form of bar graphs in Figure 1. The major factor affecting the rate of pecking on the observing key appears to be whether or not there is a substantial difference between the frequency with which grain is delivered when the food key is green and the frequency with which it is delivered when the key is red. Under the VI/EXT and the EXT/VT procedures, observing rates were almost always high. The principal exception was the rate under EXT/VT for Bird 21. This bird failed to recover its observing performance following a block of sessions in which it was exposed to the uncorrelated procedure. Under the VI/VT and uncorrelated procedures, observing rates were usually low. Here the major exception appears to be Bird 29, which continued to peck the observing key at a fairly substantial rate without regard to the contingency on the food key.

Whether the schedule of reinforcement on the food key was response dependent or response independent did not appear to have a comparable influence on the rate of pecking the observing key. Birds 21, 25, 26, and 28 pecked that key at a higher rate when the food was response dependent (VI/EXT) than when it was response independent (EXT/VT), but Birds 20, 22, 27, and 29 did just the opposite. On the other hand, although the rate at which the pigeon pecked the observing key was never very high under a VI/VT schedule of reinforcement, in all of the 10 possible comparisons for temporally contiguous (immediately succeeding) blocks of sessions, it was higher when the stimuli were correlated with the component schedules than when they were uncorrelated (Table 1: VI/VT vs. Uncorrelated). The only reversal occurred in an instance in which the blocks to be compared were not adjacent in time (Bird 21, first and fourth blocks). These data indicate that there was a systematic effect, although it was small.

DISCUSSION

As has just been noted, the birds pecked the observing key at a higher rate when the resulting red or green illumination was correlated with the presence (VI schedule) or absence (VT schedule) of a pecking requirement on the food key than when it was not correlated. This result indicates that information concerning response requirements—that is, stimuli paired with different response costs—has some reinforcing value, but the effect is not a large one. Even though there was a substantial difference between the rates of food-key pecking in the *presence* of green and red (discriminative control) when these colors were accompanied by the response-dependent (VI) and response-independent (VT) schedules, respectively, the effectiveness of these colors as *reinforcers* appears to have been much smaller than when one color was accompanied by a schedule that involved the delivery of food (either VI or VT) and the other by no food (EXT). Furthermore, comparisons of the rates of pecking the observing key when in one case the response-dependent (VI) and in the other case the response-independent (VT) food delivery was alternated with extinction failed to yield any evidence of a difference in the effectiveness of the two procedures. Neither the response requirement per se nor the resulting increase in the energy expended by pecking the key seemed to have a major influence on the effectiveness of the accompanying stimuli (green and red) as reinforcers.

One implication of our failure to find a systematic difference between the rates of observing under procedures in which responses were or were not required to produce food is that the conflict between responding and nonresponding to which Berlyne (1957) made appeal in his original formulation of the information hypothesis is clearly not a critical factor, at least, in the maintenance of observing. More generally, the finding that pigeons do not peck a key at substantial rates to procure information as to whether a response is or is not required, coupled with completely negative findings on information as to where to respond (Bowe & Dinsmoor, 1981, 1983), suggests that the concept of "information" is not very useful in predicting when stimuli will be effective as conditioned reinforcers. The reinforcing value of predictive stimuli is determined by the reinforcing value of the events they predict.

Expectancy Theories

Our data also suggest that limits may need to be placed on theoretical approaches that use "expectancy," rather than reinforcement, as their central construct (e.g., Bolles, 1979; Boneau, 1974; Dember, 1974; Dickinson, 1980; Gibson, 1969; Irwin, 1971; Tolman, 1948). Although these accounts have rarely been developed in great detail, it seems fair to say that in general they portray the experimental organism as a biological system that routinely acquires information concerning sequences of events (including antecedent stimuli, responses, and consequences) encountered in its immediate environment, even when the subsequent outcomes are neither reinforcing nor punishing. Each time the final event (e.g., entry into goal box) occurs, following the initial stimulus and the subject's response, the expectancy is said to be confirmed and thereby strengthened (for a formal analysis, see MacCorquodale & Meehl, 1953, 1954). The "valence" can be added later, as in the latent learning or sensory preconditioning experiments (Rashotte, 1979; Seidel, 1959; Thistlethwaite, 1951). The data from our experiments do not necessarily bear on the issue of the registration and retention of information after the subject observes a given stimulus, but they do suggest a restriction on the stimuli with which it will make more than cursory contact. Having eliminated reinforcement at one point in their system, expectancy theorists may find themselves required to readmit it at another.

Optimization

The small size of the effect that we have been able to attribute to pecking requirements in the present study is consistent with the general tenor of the findings obtained in studies using "choice" (concurrent-chains) procedures. In most cases, the relative rate of responding during the initial links of a concurrent chain does not seem to be affected by pecking requirements that may be included in one terminal link but not in the other. After reviewing the literature on this issue, Moore and Fantino (1975) and Fantino (1977) have suggested that the only responding that has a negative impact on the subject's choice of a given alternative is that required during discriminable periods of nonreinforcement. If the effect of the response requirement were based on energy cost, effort, or fatigue, then it should be an inescapable consequence of responding and should be found under a wide variety of circumstances. The implication of such a severe restriction on its generality is that in those instances where an effect is obtained some other principle must be involved.

Note that Ferster and Skinner (1957), who studied key pecking for a number of years using ratio as well as interval schedules, never felt a need to refer to any form of response cost in accounting for their results. It should be kept in mind that the particular forms of behavior recorded in operant chambers were deliberately "chosen because they can be easily executed, and because they can be repeated quickly and over long periods of time without fatigue" (Ferster & Skinner, 1957, p. 7). The available data indicate that the choice was successful and that behavioral data based on pecking are not sensitive to this dimension.

It may seem that the insensitivity of the pigeon to the cost of pecking negates the use of this preparation for laboratory simulations of the behavior of foraging for food in a natural setting. At a formal level, at least, the optimality model favored by behavioral ecologists is based on the net rate of intake when the energy cost of the necessary behavior is subtracted from the energy acquired by consumption of the resulting foodstuff (see, e.g., Kamil & Sargent, 1981; Lea, 1979). But in most instances the behavioral topographies involved in the alternative courses of action are sufficiently similar that differences in rate of energy expenditure can safely be ignored. That is, the costs cancel out, leaving only the rate of energy acquisition (or "delay" until next reinforcer—see Fantino & Abarca, 1985) as a determinant of how and where the organism spends its time. (Whether the number of calories provides a suitable metric for the assessment of reinforcing value is another story, e.g., Collier, 1962; Sheffield & Roby, 1950.)

Economic Models

In economic models of behavior, the food or water delivered to the experimental subject has typically been treated as a commodity to be purchased by the expenditure of a certain number of responses (e.g., the "behavioral price" of Rachlin, Green, Kagel, & Battalio, 1976) or as a wage to be earned by a certain amount of "productive labor" (Allison, 1983). The implication of an economic rationale is that the number of reinforcers provided by the experimenter is "worth" a certain number of responses to the subject and that the ratio at which this equivalence occurs can be modified by changes in supply and demand. In the quantities determined empirically under a specified set of conditions, the reinforcers and the responses are commensurate in value. But our data and those obtained under concurrent-chains procedures suggest that the number of pecks the pigeon produces under interval schedules, at least, are not of commensurate value. They are of substantially less importance to the bird than the resulting deliveries of grain. This conclusion does not impinge upon the functional relations described by economic models of behavior, but it may raise a question concerning their basic rationale and perhaps even their correspondence rules and the extent of their domain.

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